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Utilizing NX Advanced Simulation for NASA's New Mobile Launcher for Ares-1

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Introduction

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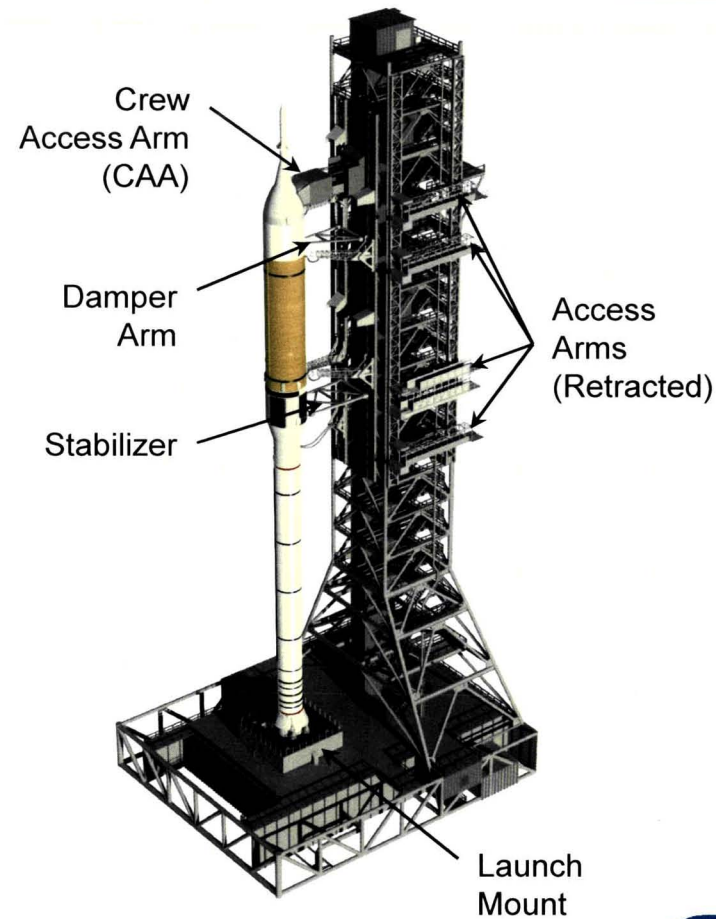
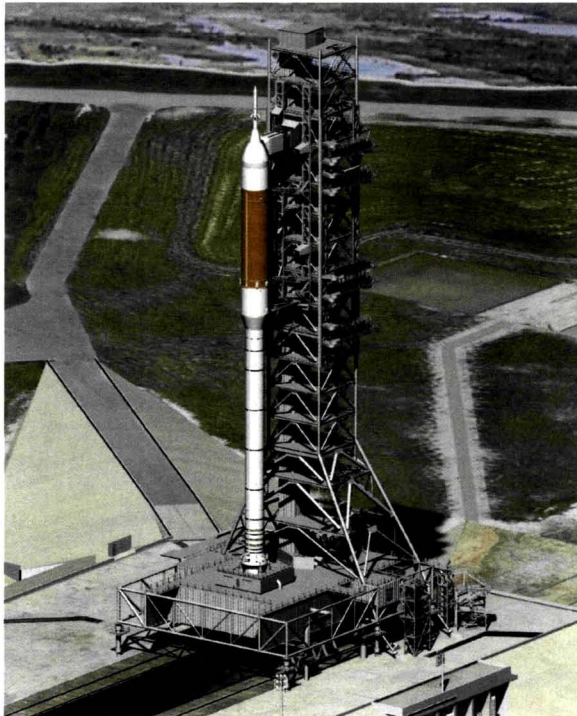


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System Overview

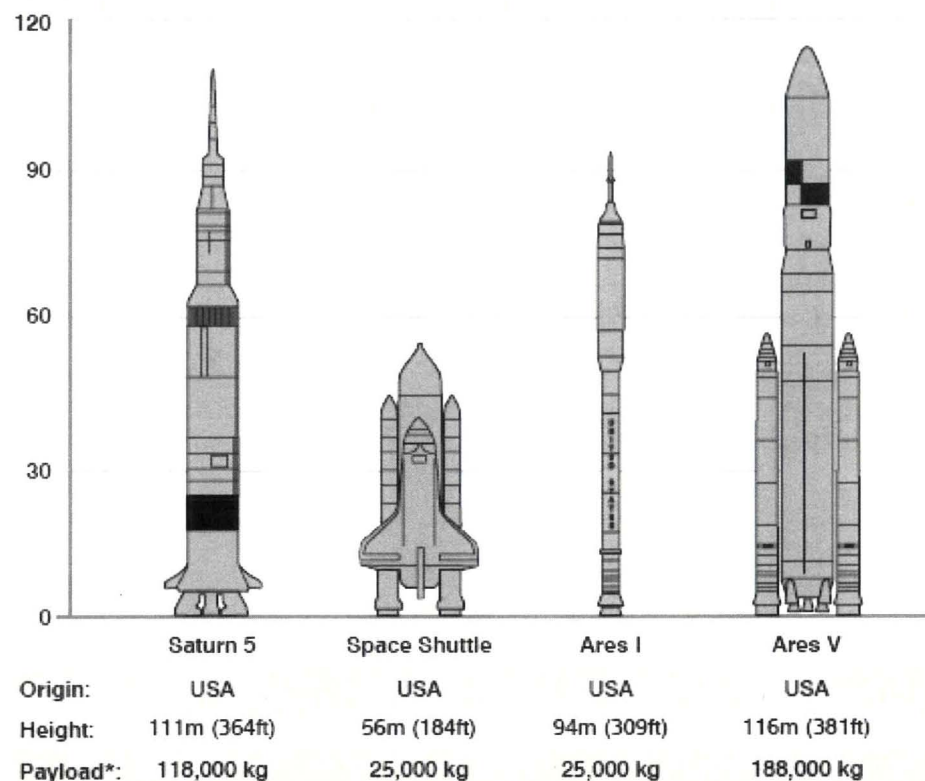




Relative Sizes

Launch Vehicles

Metres



* To low-Earth orbit

SOURCE: NASA



Requirements

- Requirements for Design **and** Analysis
 - Loads Requirements
 - Finite Element Modeling Requirements
- SDVR – Structural Design and Verification of Requirements
 - Acceptance by test, analysis, or both
 - Most systems initially by analysis
- LCP – Structural Loads Control Plan



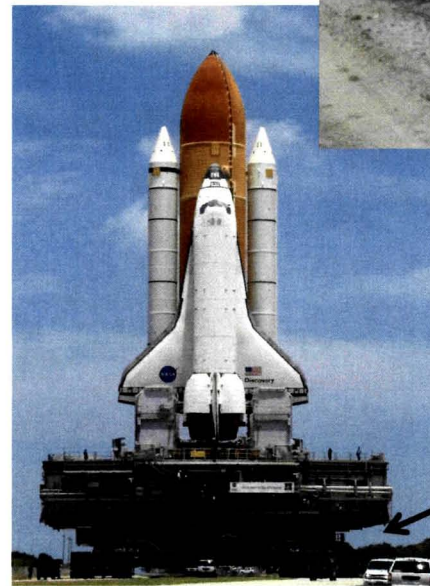
Loads Control Plan

- Software Requirements
 - Quote: “The format will be a NASTRAN bulk data file”
- Modeling Requirements
 - All elements, nodes, csys, materials, properties, etc. have ID Ranges
 - 8 digit number
 - a-b-xxx-xxx (e.g. for Mobile Launcher is 02,xxx,xxx, first grid ID is 2,000,000, etc.)
 - Relates to System Element (First Stage, Orion, Mobile Launcher, etc.)
 - Units
 - Coordinate Systems
 - Must have one master CSYS
 - May have several sub-CSYS if dependent on master.
 - Constraints
 - 9-b-xxx-xxx (ML constraints start at 92,000,000) (can't assign in sub-FEM for AFEM!)
 - No AutoSPC!!!
 - “The System Element models will not rely on the automatic single point constraint (SPC) function within NASTRAN.”
 - Run SPCGEN to get .pch
 - Add back to model as constraint set with SPCADD



Design Challenges

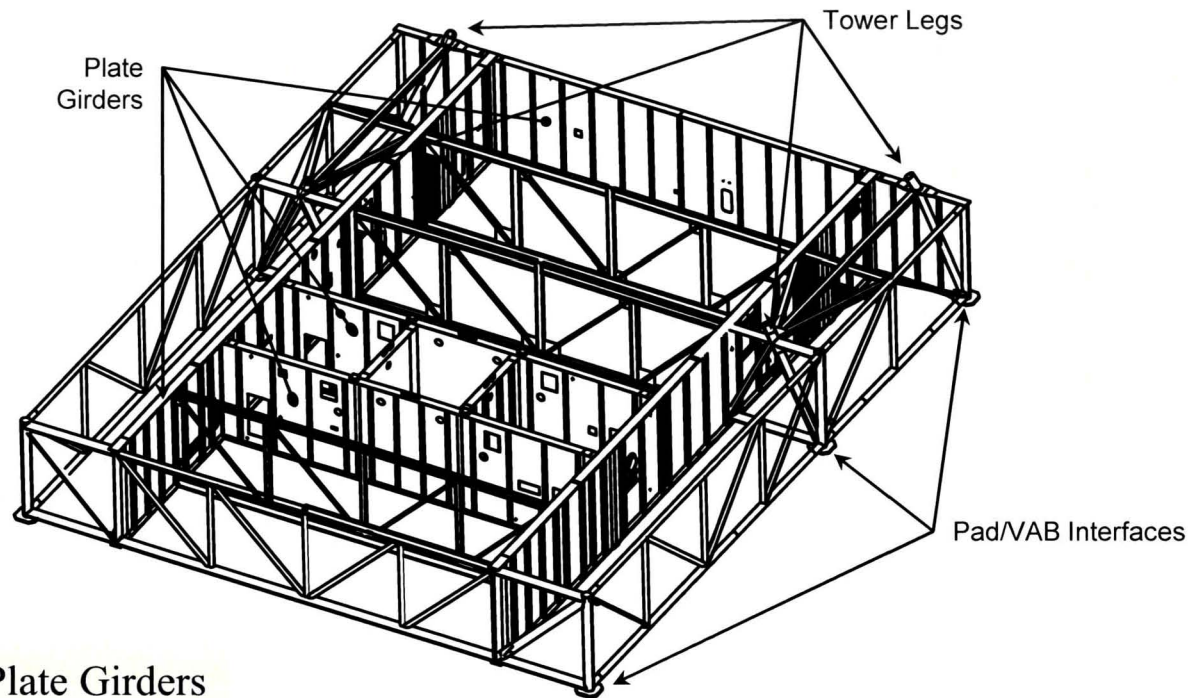
- Short Time Frame
- Don't Exceed Current Infrastructure Capacities
 - VAB Supports
 - Crawler Transporter
 - Crawlerway
- Differences
 - Apollo
 - Tower with liquid motor
 - Shuttle
 - No tower with solid motor
 - Ares I & VI
 - Tower AND solid motor



Crawler Transporter



Base Framing

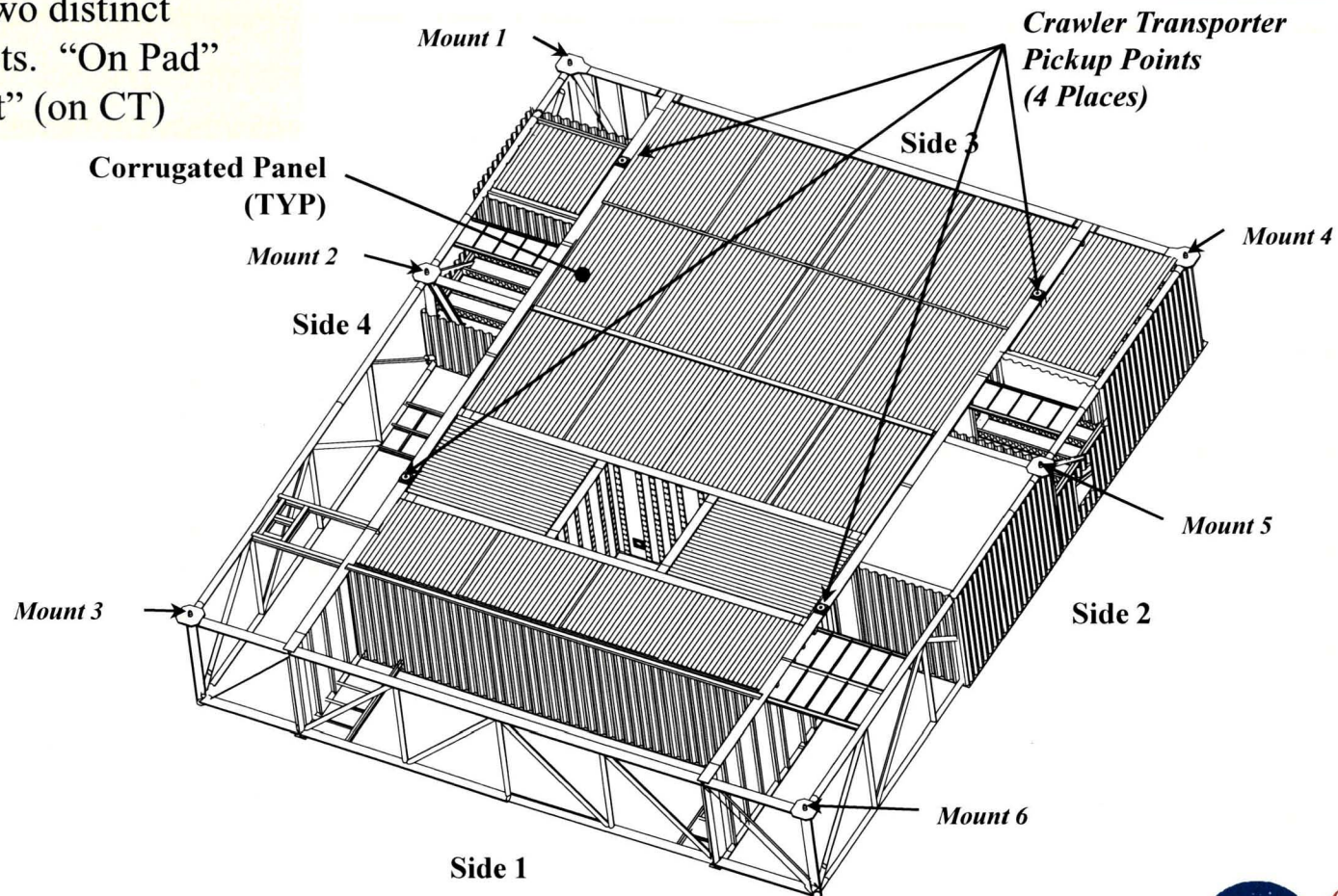


Combination of Plate Girders
and Trusses

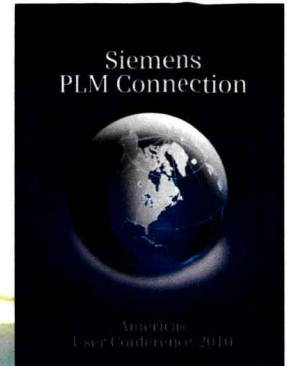


Underside of ML

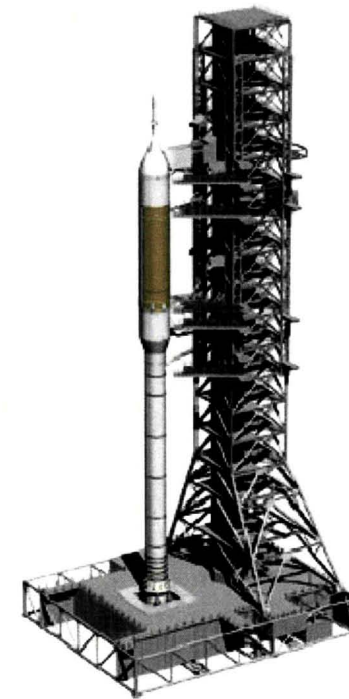
Model has two distinct constraint sets. "On Pad" and "Rollout" (on CT)



3D CAD Data Origin



- Wanted 3D CAD Geometry
 - Pro /E Model (Not NX)
 - Required Translation
 - STEP
 - Parasolid (mm always)
 - DXF
- Grab Pro/E Skeletons for centerlines (DXF)
- Maintain Solid Assembly Hierarchy
 - Parasolid, STEP
- Multi-step with overlay
 - Solids then wireframes (on different layers)

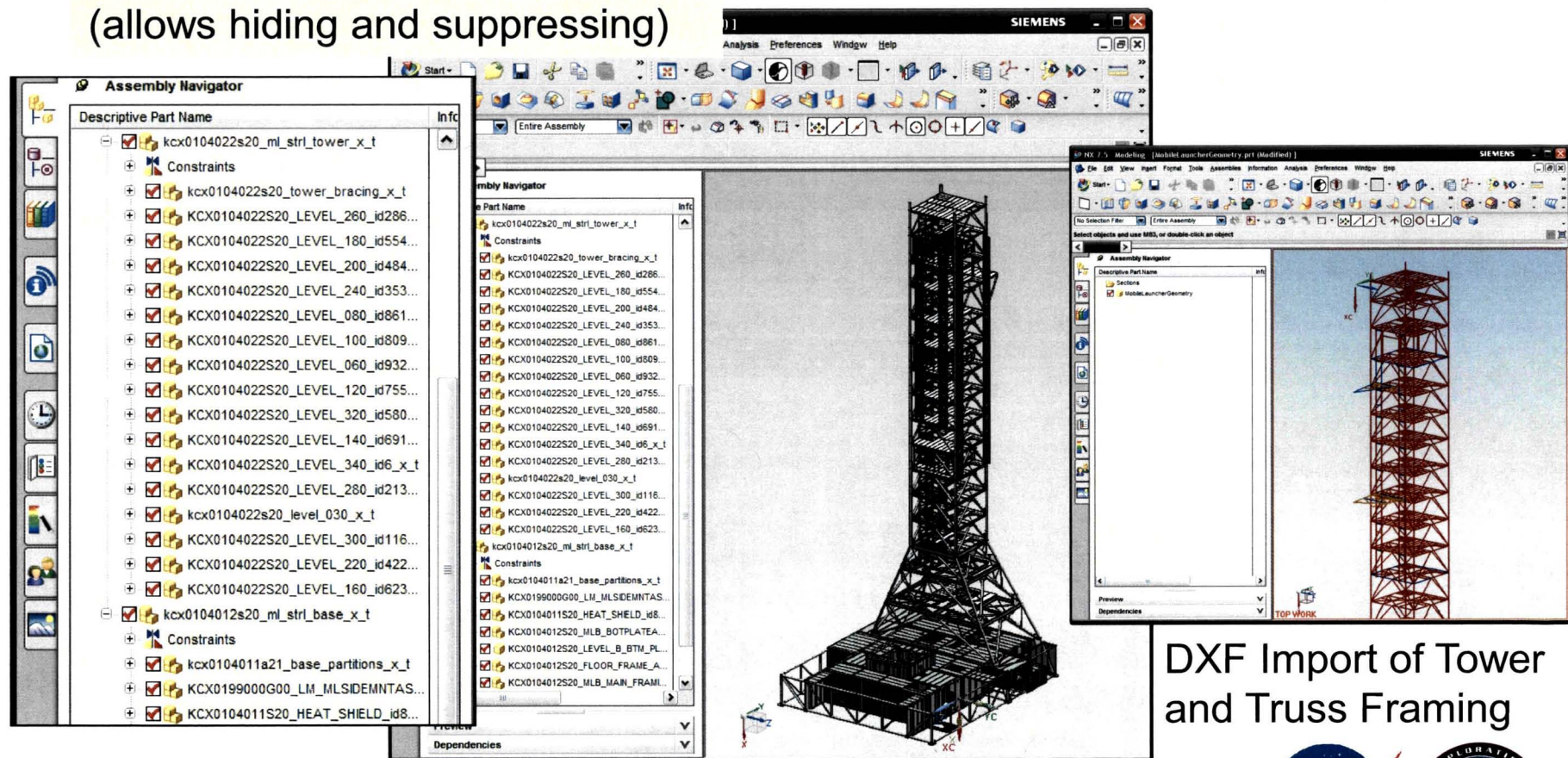


Pro/E Model



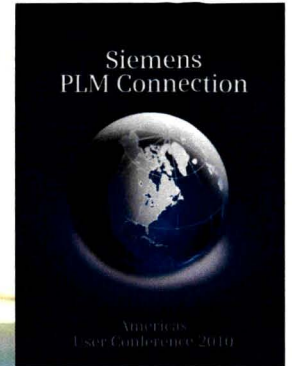
Translated Model

Hierarchy Maintained
(allows hiding and suppressing)



DXF Import of Tower
and Truss Framing

Modeling Approach



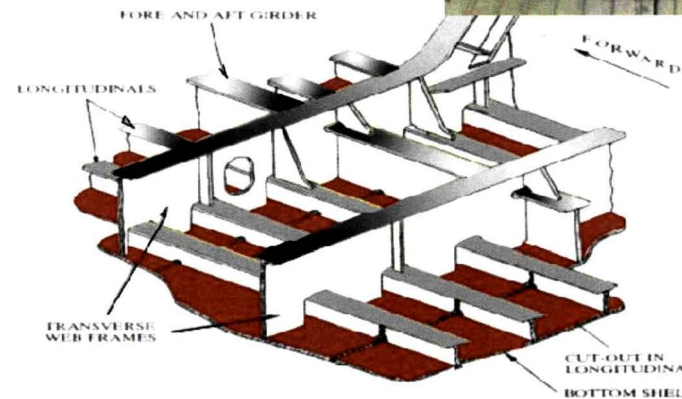
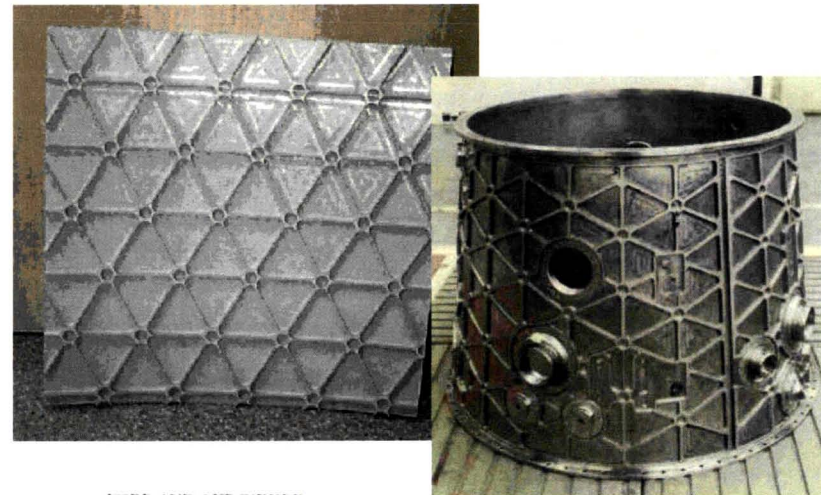
- Meshing
 - Lots of preparation before first element
 - Mid-surfacing, partitioning, etc.
 - Planning intersections!!!
 - Mesh testing
 - Behaves as expected
 - Don't paint yourself into a corner
 - Hiding geometry for Phase 1 Dynamic Model
 - Limit floor framing resolution
 - Not needed for primary tower modes, etc
 - Will produce spurious modes
 - Very few plate elements per “partition”
 - Properly planned model can be refined later
 - Stress models, etc.

Spent as much time in
Modeling Application as
Advanced Simulation!
(maybe more)



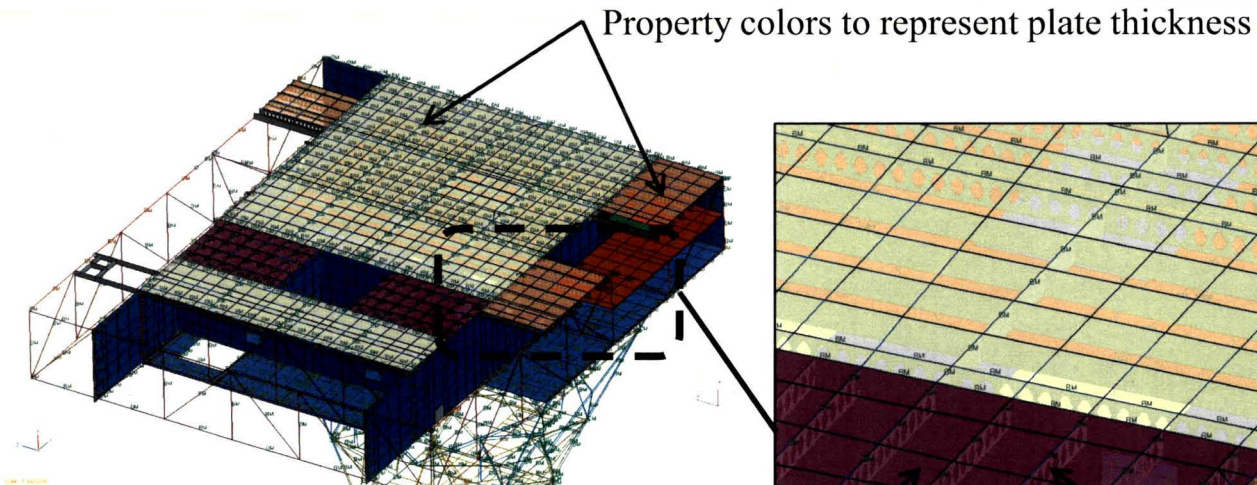
Mixed 2D & 1D Meshes

- Beams under plates
 - Common Modeling Scenario
 - Deck Plating over floor framing beams
 - Stiffener reinforced panels
 - Stiffening rings in pressure vessels
 - Isogrid structure



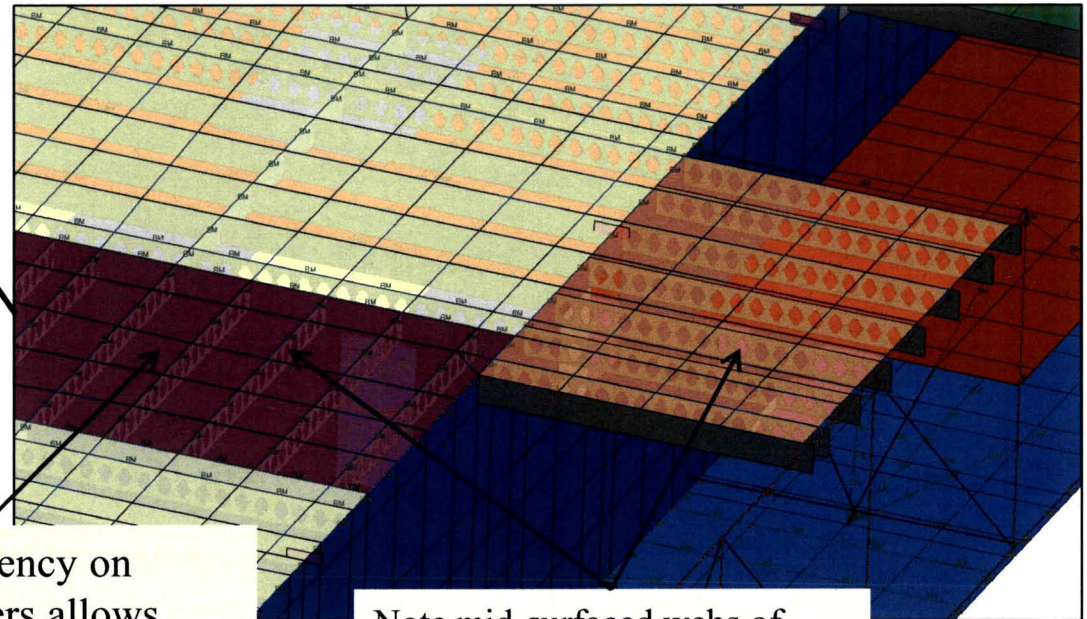


Partitioning & Intersections



Divide Face used
on deck surfaces
using beam webs
as tools.

Setting translucency on
surfaces on layers allows
overlay inspection of
partitions.



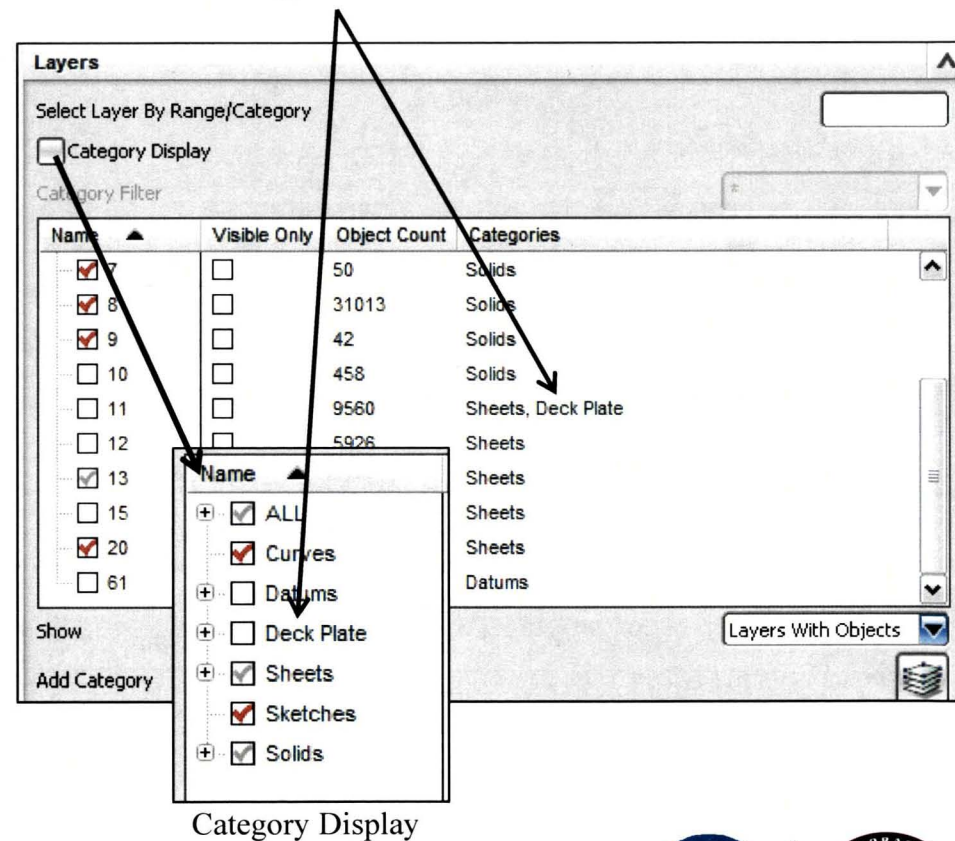
Note mid-surfaced webs of
castellated beams. Flanges
moved to junk layer in case
needed later.



Layers & Groups

- Three ways to control selection and visibility
 - Navigator
 - Groups
 - Layers
- Layers Have Underestimated Power
 - Using “Visible Only” removes entities from unintentional selection
- Control

Meaningful Names

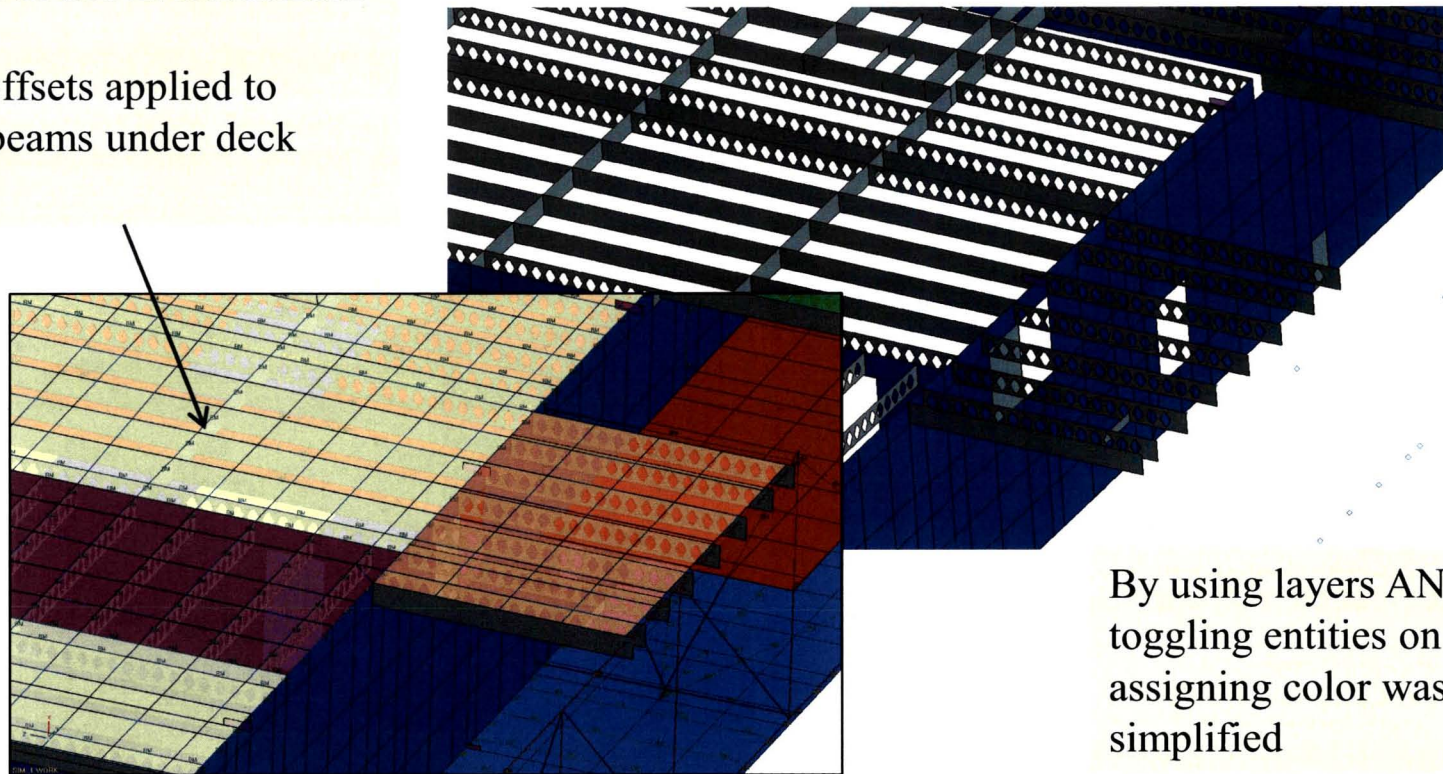




Toggling Layers & Meshing 1-D

Beams meshed along Divide
lines AFTER PLATE MESH

Beam offsets applied to
match beams under deck

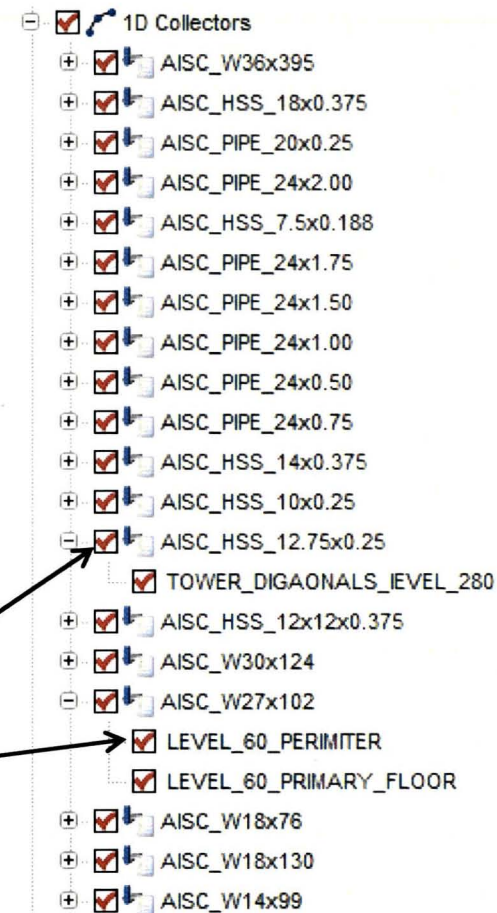


By using layers AND groups
toggling entities on and off and
assigning color was greatly
simplified



Collectors

- Collectors are huge time savers
 - Drag and Drop physical and material property changes
 - Color Coding (improved in 7.5)
 - Meaningful Naming
 - Tied to Physical and Material Properties cards in NASTRAN



Meaningful Property Names

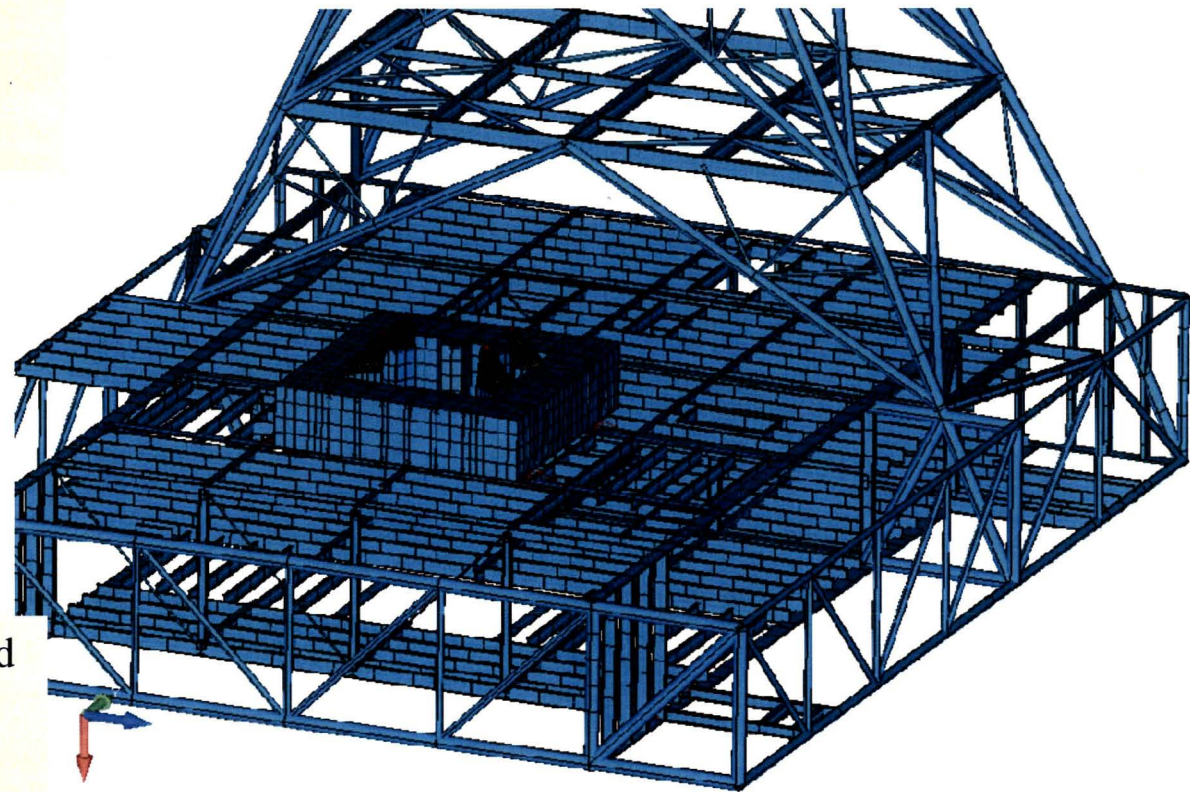
Meaningful Entity Names

Some names “round-trip” to NASTRAN deck and back. Many do not!



Beam Arrangement

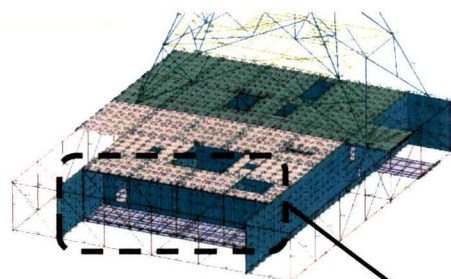
Deck plating removed
to show beam structure
and number of end release
locations



FEMAP used to preview and
check CBEAM orientation,
etc.
(Now can use NX 7.5)

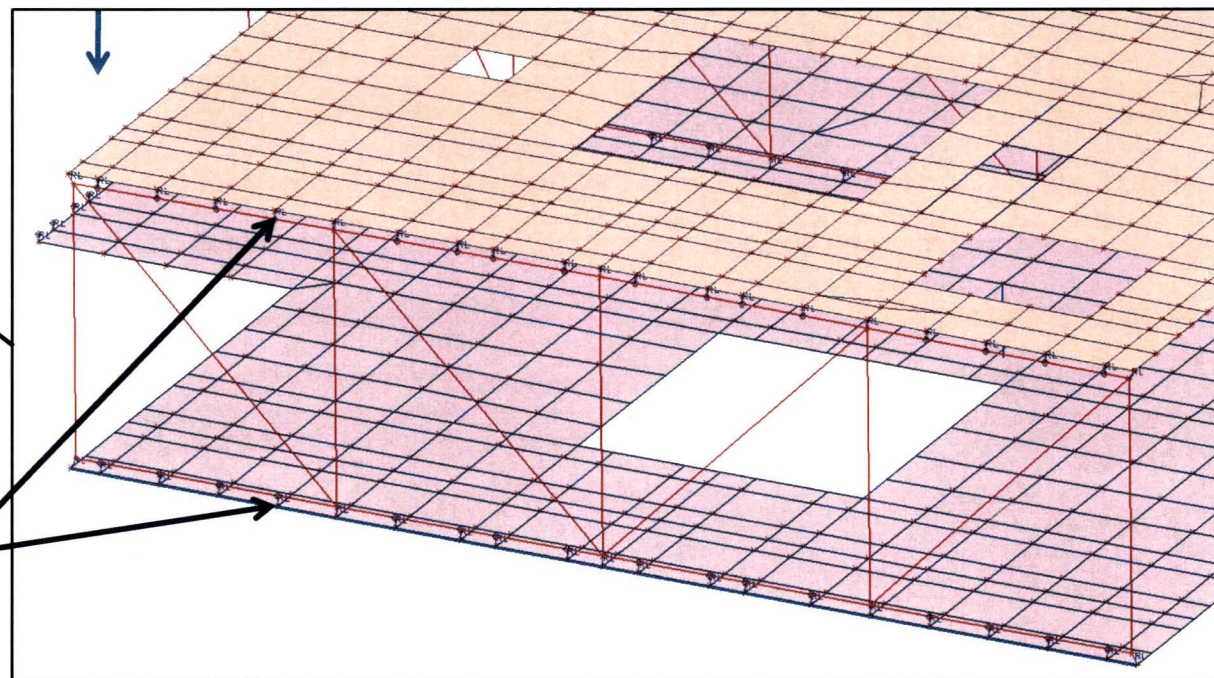


Beam Offsets vs RBEs



Offsetting trusses would produce unwanted geometry at work points. RBEs were used to make connections on horizontal members

Mesh geometry for offset beams may be easily created by creating "offset curves" in modeling. Can be associative as well.



Offsets used on deck framing may need to be changed to RBEs for non-linear runs



Creating many RBEs

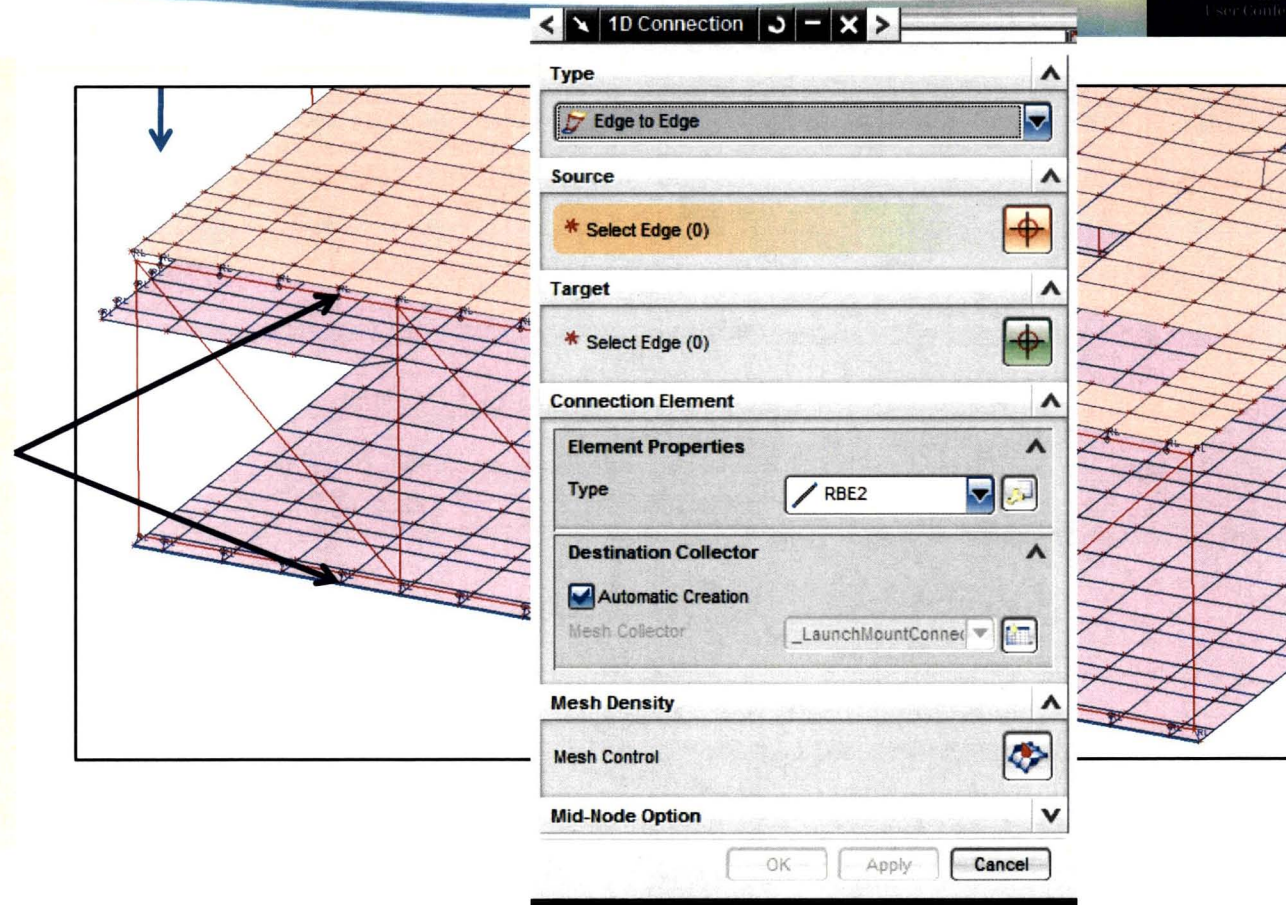
Created RBE links with 1D Connection, not 1D Mesh.

Had deck plate 2D mesh first.

Project RBEs onto 1D wireframe to create mesh points.

Alternatively create mesh points by projecting existing nodes onto wireframe.

Create CBEAMs that automatically pick up the mesh points or existing nodes. Set element length larger than nodal distance to ensure 1 CBEAM between mesh points (if desired).

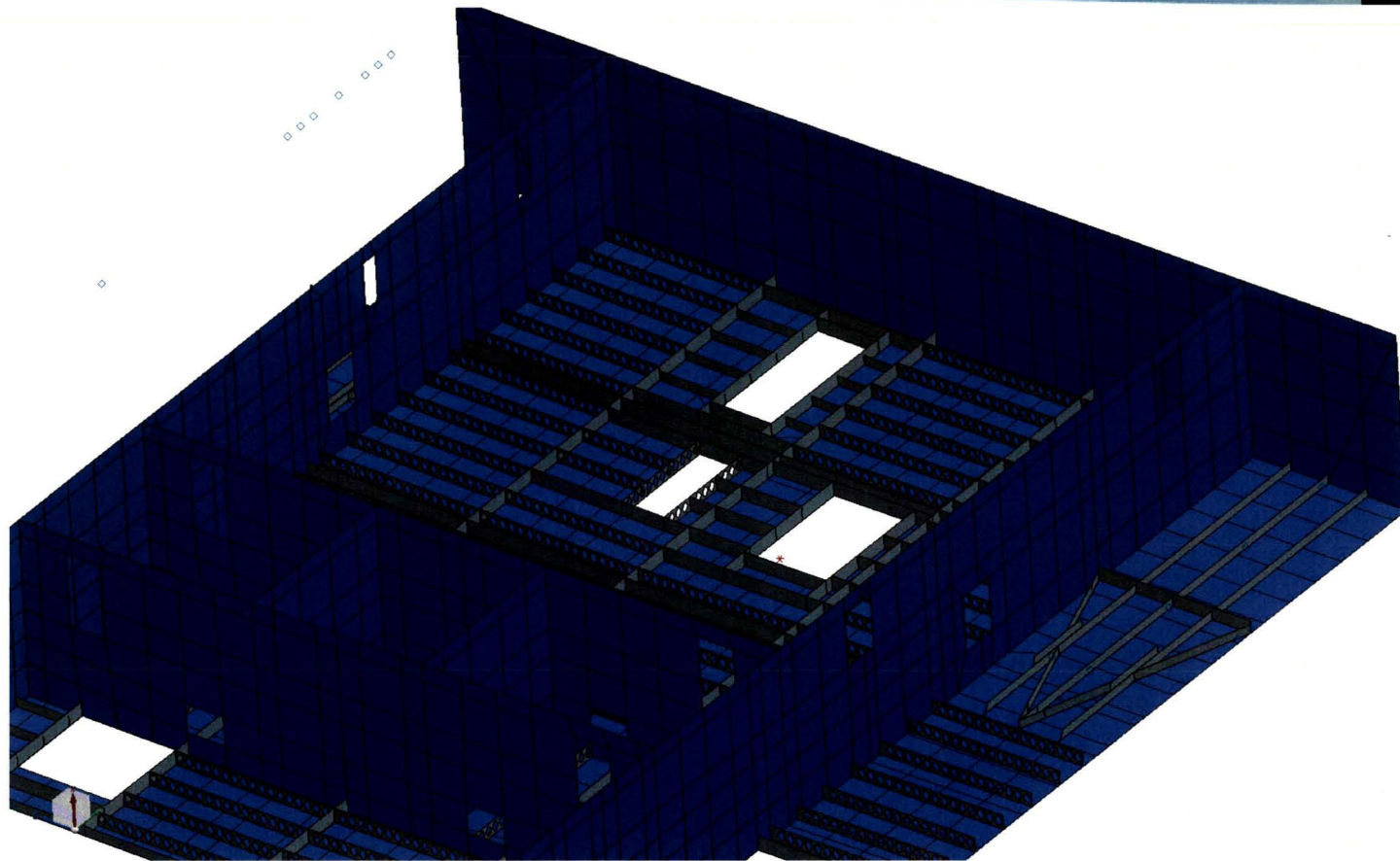


iPhone, iPad, iPrt

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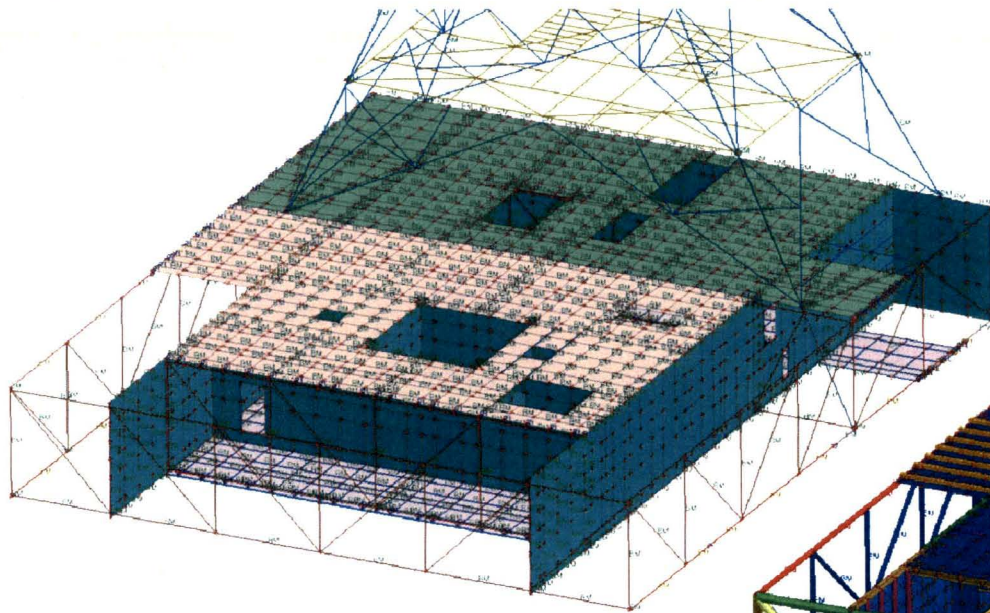


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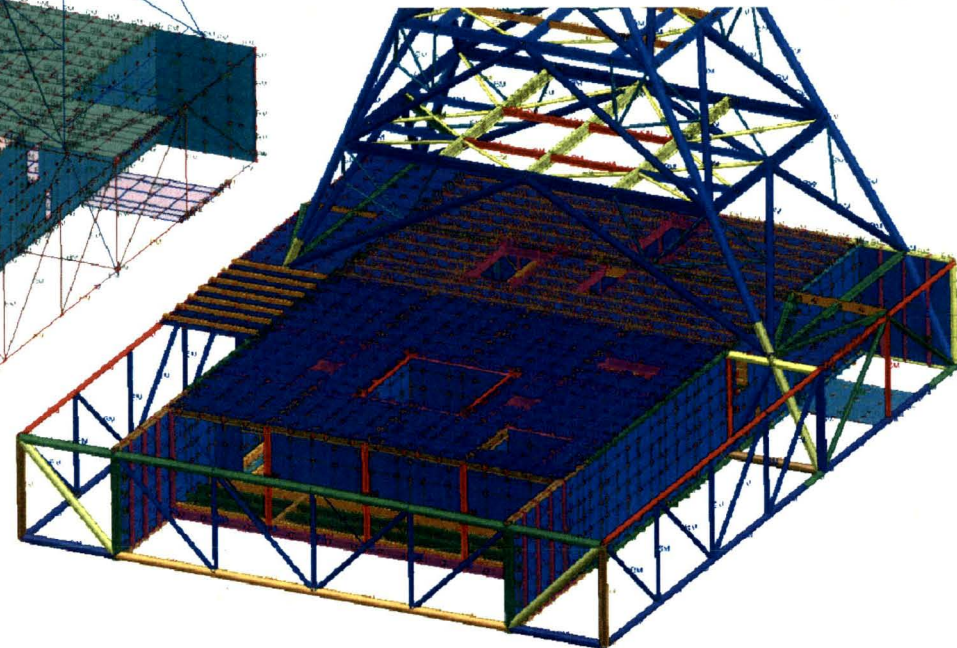




Finished Base



NX 6 Wireframe
Mesh Collector Display Colors



NX 7.5 Solid Shaded
Auto Physical Property Colors



Assembly FEM

- Allows separate development of component models
- Used for Stabilizer, Damper, and Vehicle Support Posts

Simulation Navigator

Name

- ML_LA4.afm
- MobileLauncherLA4Fem_f_1.fem
- LM_analysis_sol103_f.fem
- Stabilizer_LA4.fem
- VSP_Casting_f.fem
- VSP_Casting_f.fem
- VSP_Casting_f.fem
- VSP_Casting_f.fem
- 1D Collectors
- Groups
- Fields

Assembly Label Manager

Type: Same Offsets in Component

Automatic Label Resolution

Offset to Nearest: 1

Automatically Resolve

Labels

Nodes | Elements | Coordinate Systems

Component	Label Range	Offset	Status
ML_LA4	9900001-9900004	0	✓
MobileLauncherLA4Fem_f_1	2010058-2212462	0	✓
LM_analysis_sol103_f	2500000-2503362	0	✓
Stabilizer_LA4	2700000-2700060	0	✓
VSP_Casting_f	1-4490	0	✗
VSP_Casting_f	1-4490	0	✗
VSP_Casting f	1-4490	0	✗

Validation

Options: All Components

Run Verification

OK Apply Cancel

Set and check label ranges for sub-fems

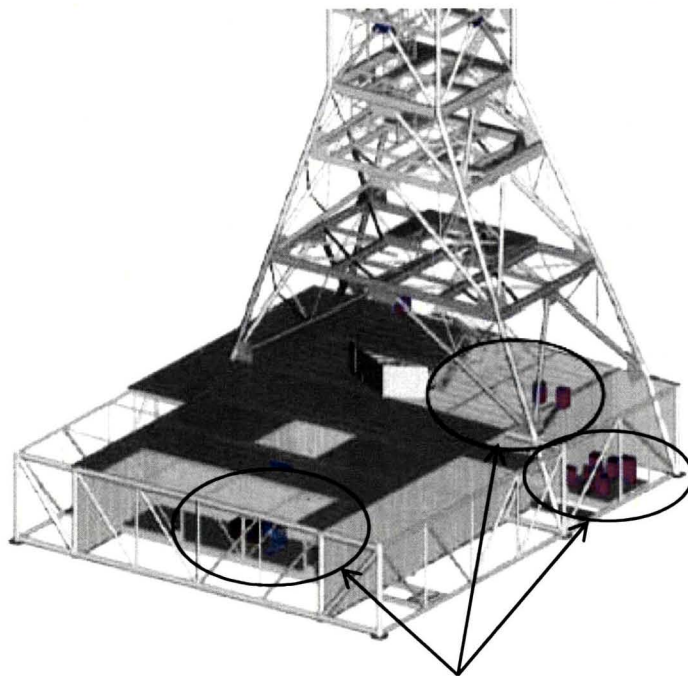
Assembly hierarchy for sub-fems. Same visibility and control as basic fem

Model Summary

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Typical Component Locations

Mass Elements

NUMBER OF GRID POINTS	= 23044
NUMBER OF CBAR ELEMENTS	= 159
NUMBER OF CBEAM ELEMENTS	= 4076
NUMBER OF CELAS2 ELEMENTS	= 18
NUMBER OF CONM2 ELEMENTS	= 599
NUMBER OF CQUAD4 ELEMENTS	= 3997
NUMBER OF CTETRA ELEMENTS	= 8972
NUMBER OF CTRIA3 ELEMENTS	= 98
NUMBER OF RBE2 ELEMENTS	= 235
NUMBER OF RBE3 ELEMENTS	= 58



7.5 Beam Improvements

Element Properties

Section Orientation
Method: Orientation Vector
☒ Specify an Element (1)

Element Label
Define Element Axis: Y
☒ Specify vector to project (1)
Reverse Direction

Section Offsets
☐ Offset End B = Offset End A
Section Placement Method: Language-Specific

End A
☒ Specify Section Location (0)
Offset in Nodal Displacement CSYS
X Offset to Shear Center: 0 in
Y Offset to Shear Center: 0 in
Z Offset to Shear Center: 0 in

End B
☒ Specify Section Location (0)
Offset in Nodal Displacement CSYS
X Offset to Shear Center: 0 in
Y Offset to Shear Center: 0 in
Z Offset to Shear Center: 0 in

Apply Pin Flags on: End Nodes of Chain
Pin Flags - End A
Pin Flags - End B
Reset to Default...

Cross Section Preview

Dimensions

Dimension	Value
DIM1	3.937007 in
DIM2	3.937007 in
DIM3	4.724409 in
DIM4	1.181102 in
DIM5	0.393700 in
DIM6	0.787401 in

Beam Section

Type: I

Properties

Illustration

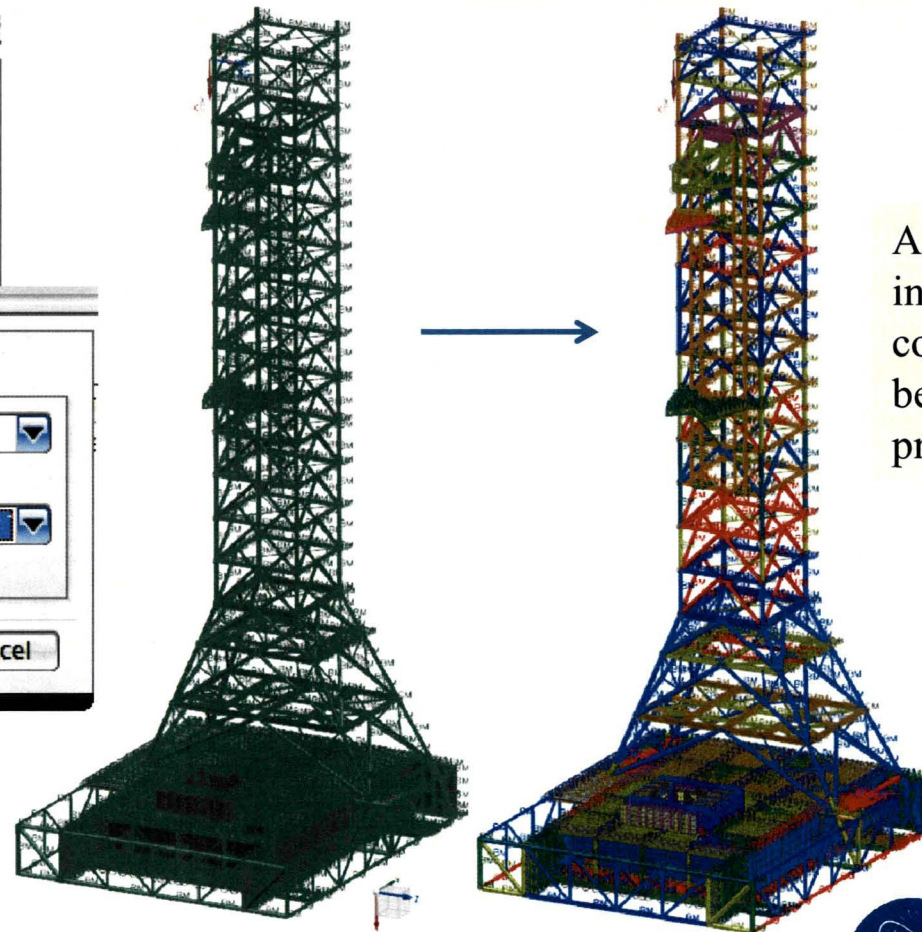
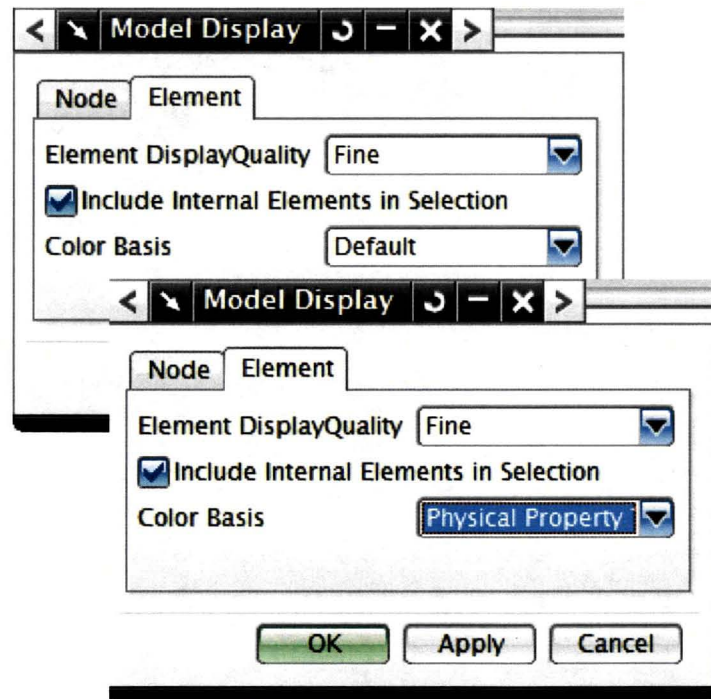
Dimensions

Evaluate Section Properties

Preview



Property Colors – Automated in 7.5



Allows visual
inspection of
consistent
beam & plate
properties



Conclusion

- Believe the Paradigm
 - Geometry Based Modeling
 - Parametrically driven models when possible!
 - “Drag and Drop” and “Right Click” GUI
 - Collectors make it fast to assign properties
 - Change on the fly
 - Run “what if” scenarios
 - 3D Beam display and Sections by Sketching
 - Color by metadata (properties, etc.)
- NX 7.5 is “Breakthrough Release” for 1-D modeling



Enhancement Requests

- Create Centerline Geometry from solids
 - Similar to mid-surfacing but creates line/wireframe geometry for 1-D meshing.
 - Edges of solids have to be offset
 - Round solid sections have no edge to mesh
- Allow simple import of .pch file as field data for things like SPCGEN
- 1-D Section Library
 - Save 1-D section sketches similar to material library
 - Define Family Table parametric sketches of cross-sections
 - Family Table of data values to drive sketch parameters
 - Would allow import of all wideflanges, channels, etc. from AISC and AA



ML Under Construction





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Thank You!

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Nashville, TN

May 24-27

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